

Tevatron Physics for Run III

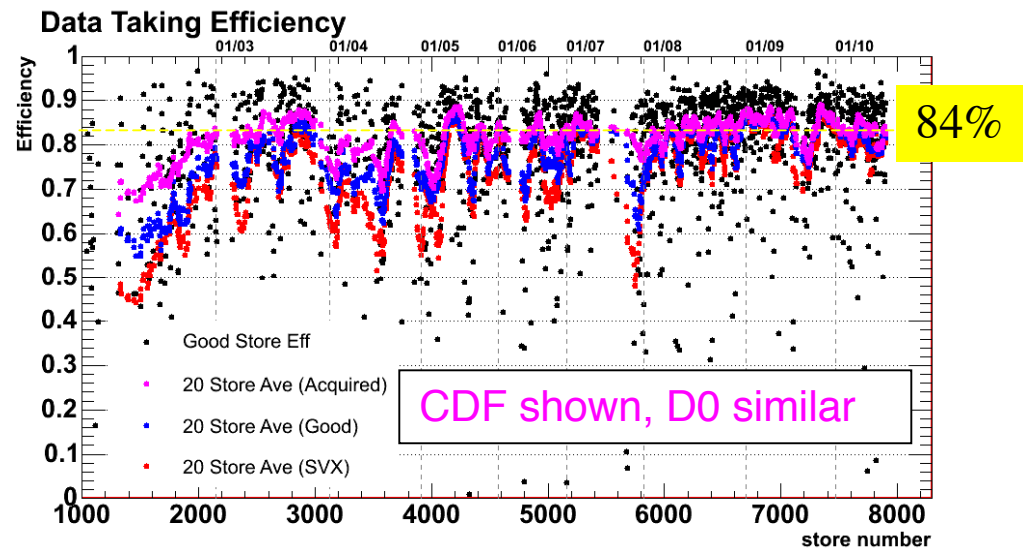
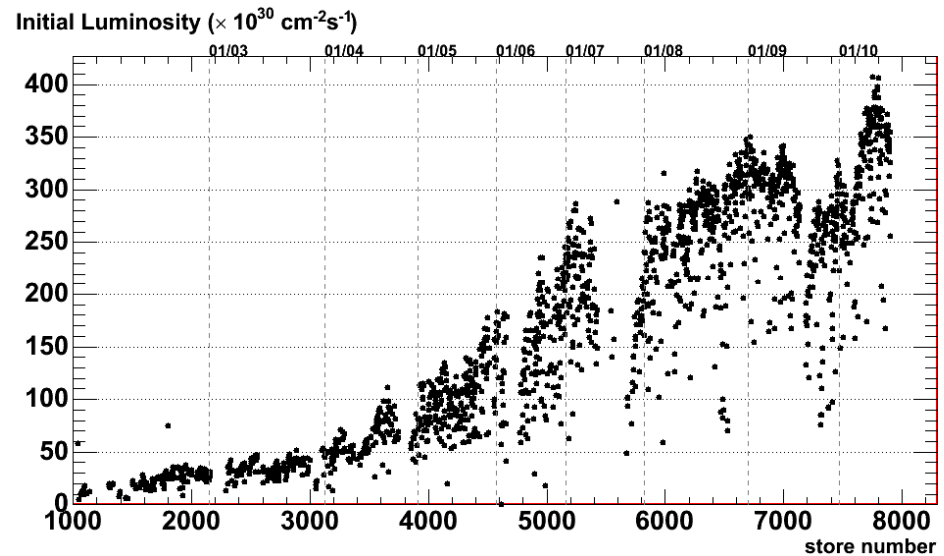
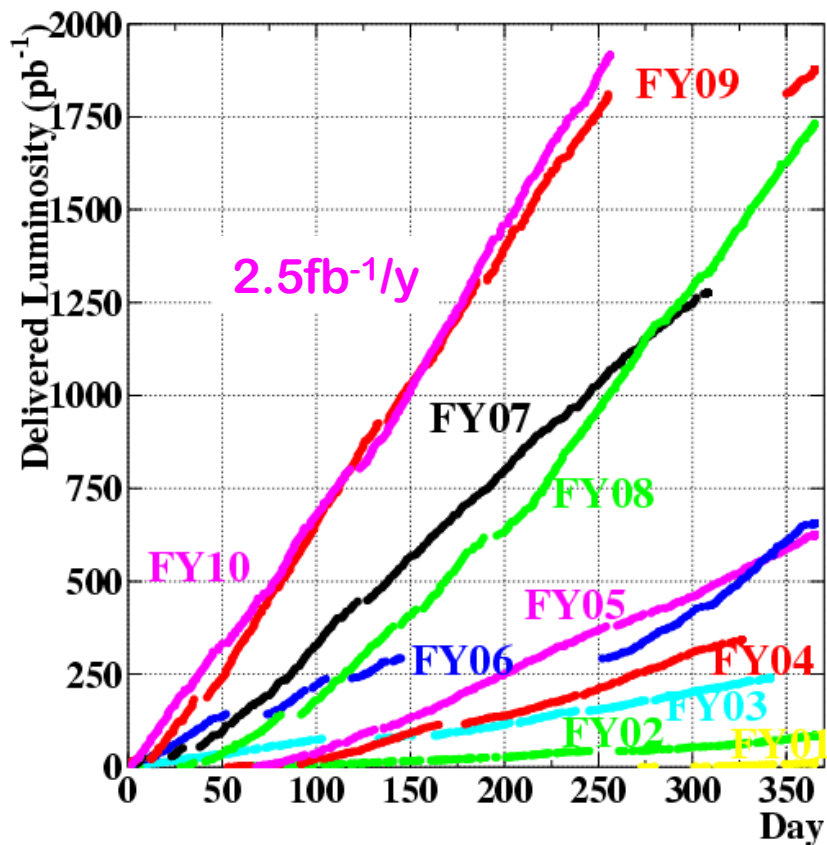
PAC 6/22/2010

G.Punzi, S.Söldner-Rembold, R.Roser, D.Denisov

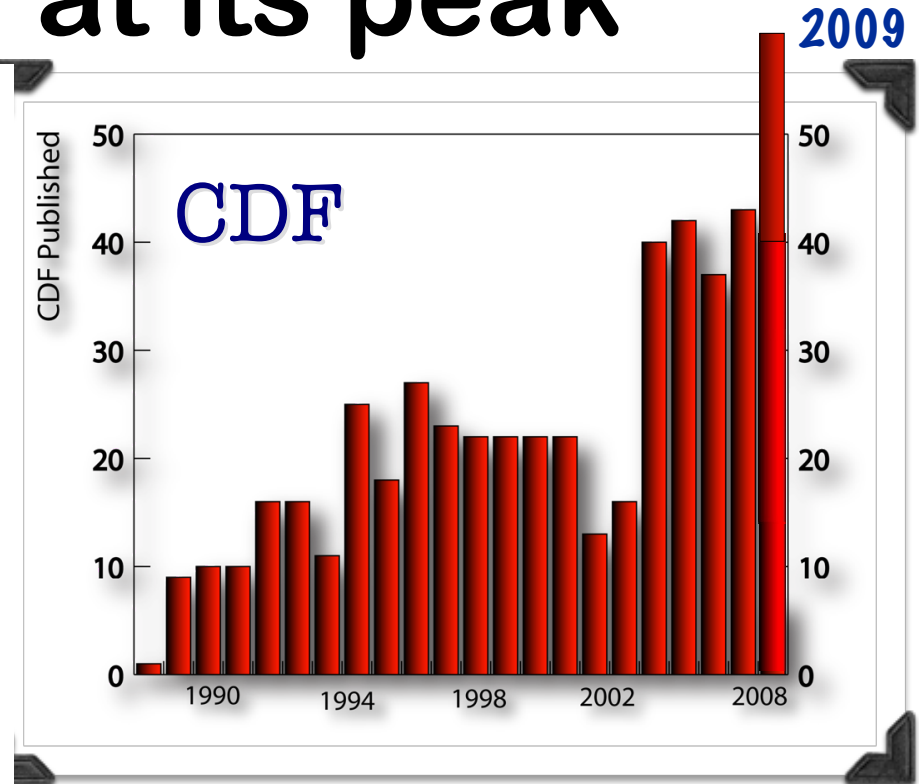
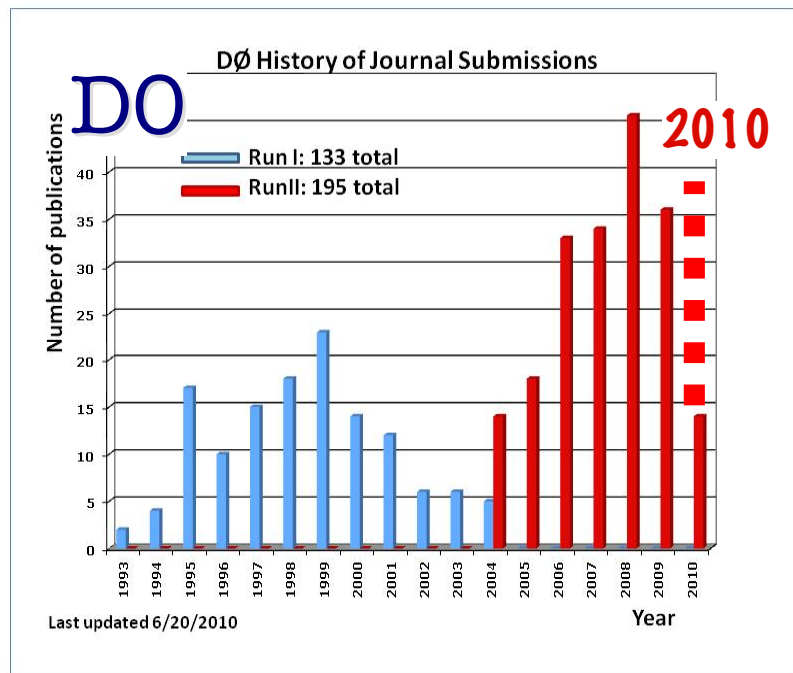
Proposal

- Run the Tevatron for a 3-year period after 2011
- Purpose: further doubling of data to attain the ultimate goals of the Tevatron program.
- Presentations:
 - Physics program I: Overview/CPV at Tevatron
 - Giovanni Punzi
 - Physics program II: EWSB at Tevatron
 - Stefan Soldner
 - CDF detector and collaboration outlook
 - Robert Roser
 - D0 detector and collaboration outlook
 - Dmitri Denisov

Luminosity and Efficiency



Reminder: a program at its peak



- Near 100 publications in 2009. Many heavily cited.
- About 60 Ph.D.'s / year over the last few years
- Scores of results Summer'09 => Winter'10 => Summ'10

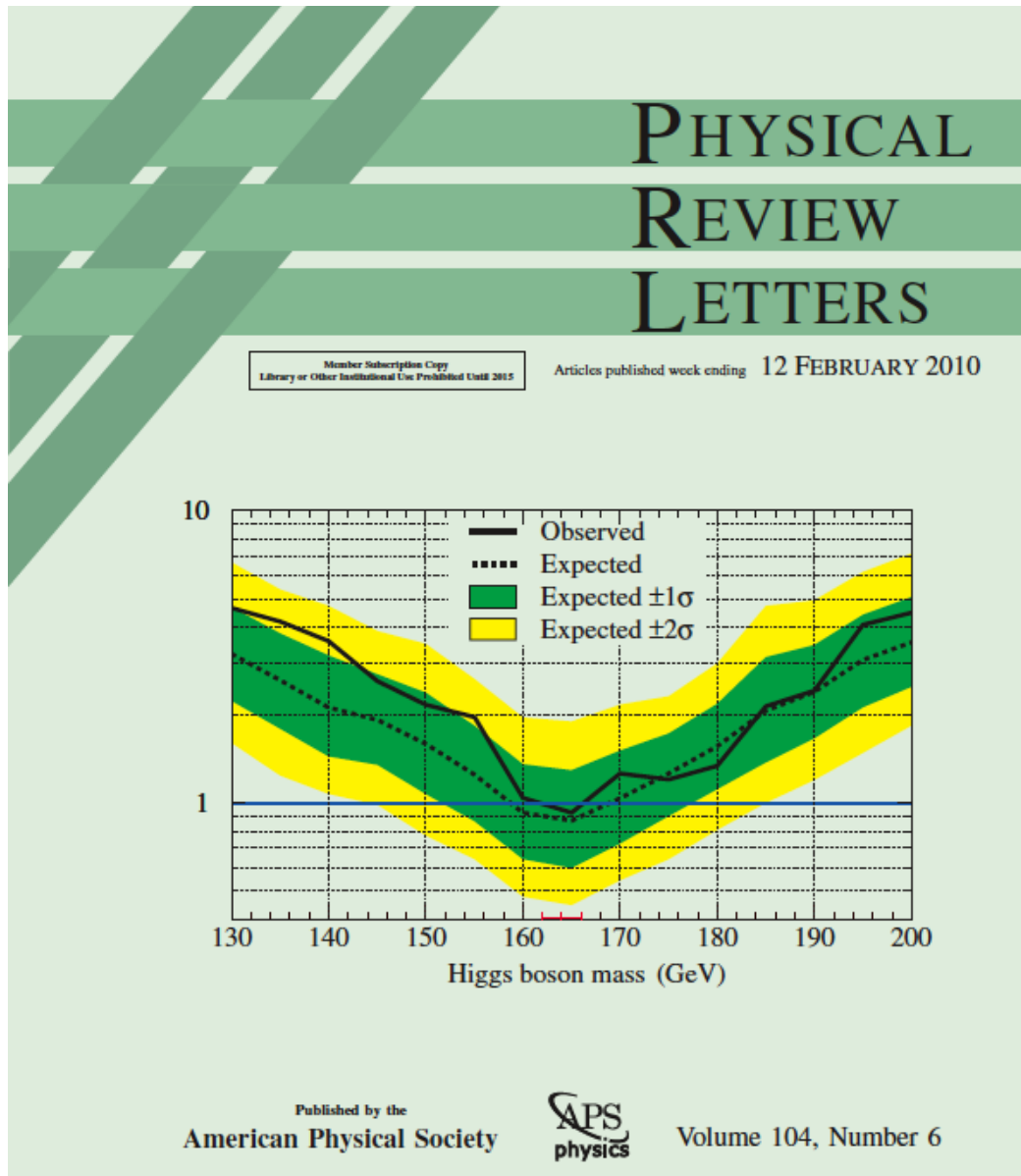
The program is not winding down, and a replacement is not yet here.

But what should we expect next ?

On the Brink Of Discovery

- The Tevatron is not the energy frontier anymore. However, it is on the brink of discovery on two central HEP questions:
 - The mechanism of EWSB
 - The search for anomalous CP violation
- They require INTENSITY more than ENERGY, unlike other searches for BSM physics (SUSY,...)
- We are just now crossing the threshold of the place where the answers of those questions lie: this is where the *real game* begins.
- The program is a SURE THING: a short-range extrapolation from current results.
- Many Tevatron results will stay as a legacy as they are complementary to other facilities

On crossing thresholds



MILESTONE Higgs paper
from CDF+D0 (>1000 authors!)

It took us 25 year of hard
work, lowering the curve,
with no result on the Higgs.

Finally we touchdown,
giving the start to the Higgs
program:

M_H excluded 162-166 GeV

*From now on, progress
will be fast. Discussion
in next talk*

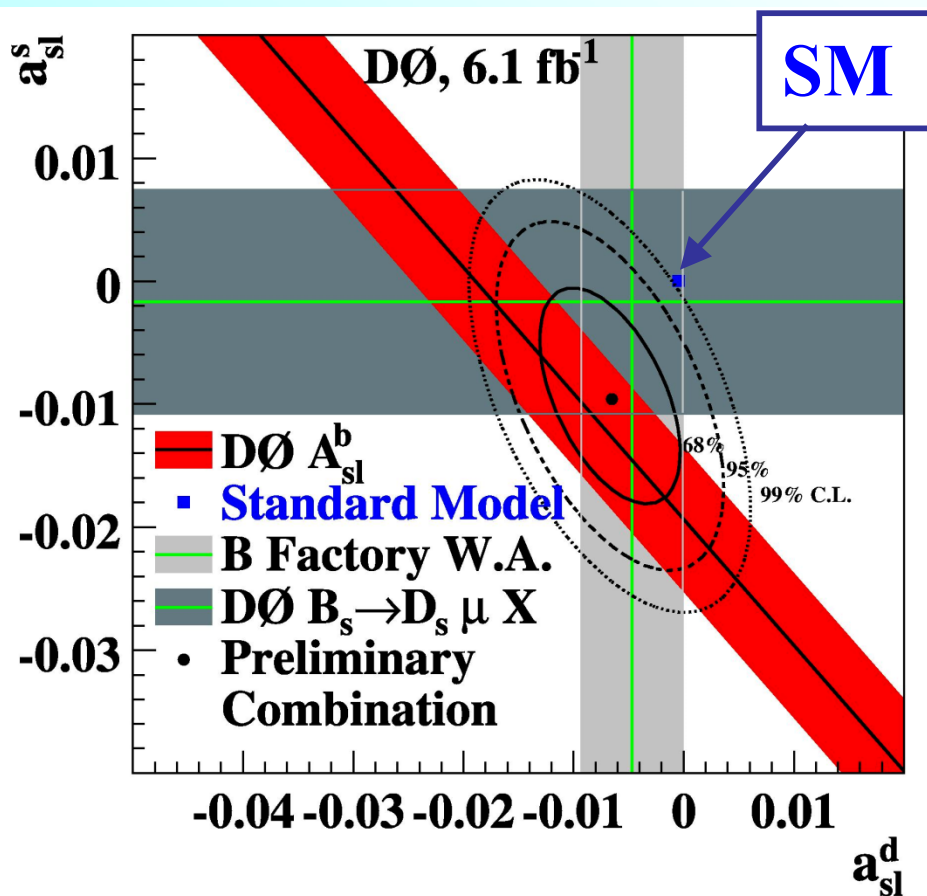
Should we stop running now ?

On crossing thresholds, #2



Fermilab Wine & Cheese Seminar, 14 May 2010

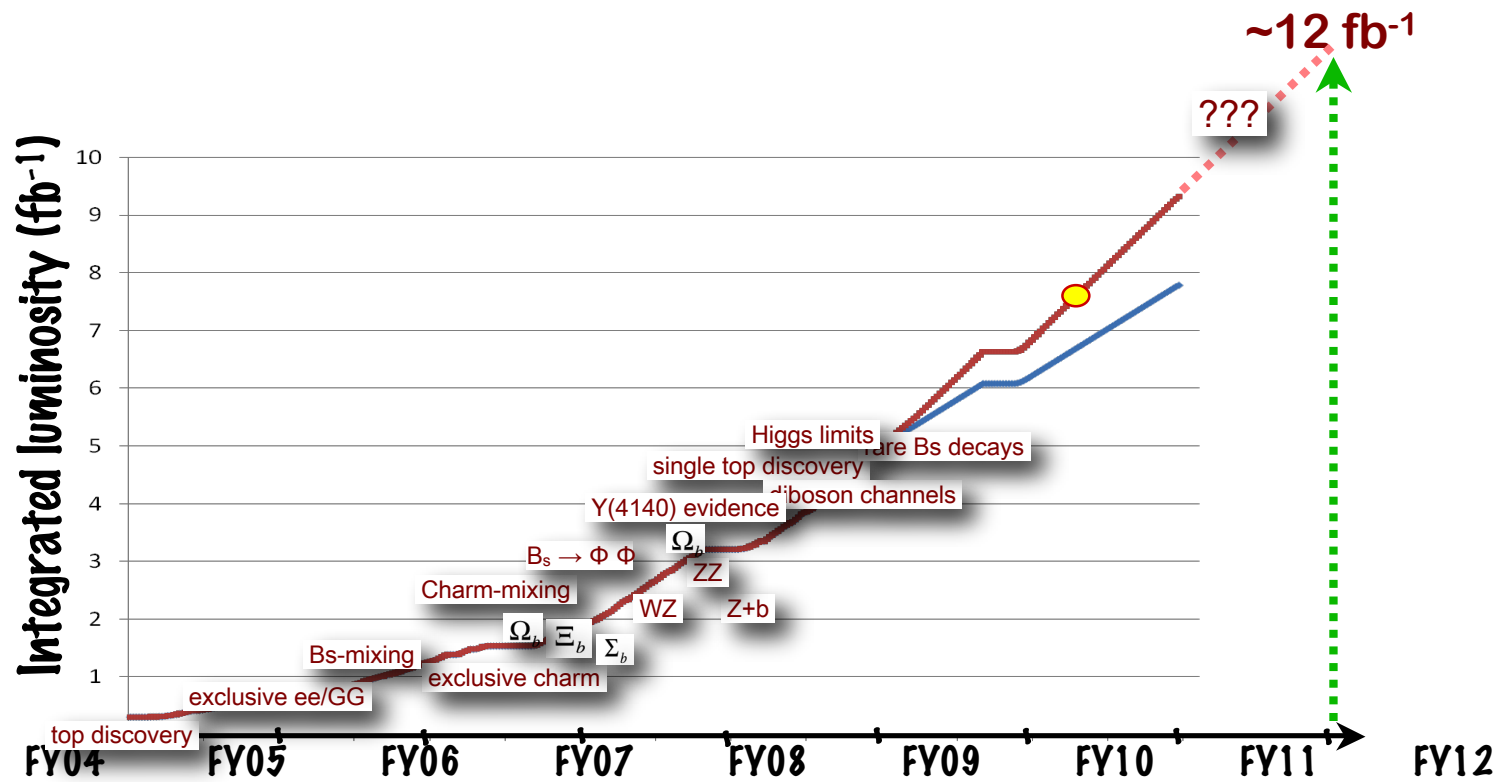
Evidence for an anomalous like-sign dimuon charge asymmetry



- A_{sl} is 3.2σ from SM
- Long-awaited first evidence for BSM CPV
- If real, we should see the effect in other measurements as well

Should we stop running now ?

Continuously pushing boundaries



- Steady flow of quality physics results - As data increases, not just increase in statistics, but wider range of opportunities: new measurements and new channels. Continuously pushing boundaries. Little to do with $\text{Sqrt}(L)$ law.
- On top of ~200 Higgs/year:
More B's than B-factories, more D's than charm-factories.
- The overall impact on science of the myriad of results is difficult to describe in a talk but is indeed very relevant.
- Tevatron an unmatched training ground for new and old physicists

Remarks on Run 3

- In addition to doubling the data, a 3-year period allows reloading a new generation of students
- Keeps a whole community engaged, allowing for multiple interests within the collaboration while pursuing the most fundamental questions.
- A great opportunity to keep up a rich and healthy scientific production while other programs are starting. Also considering the LHC shutdown at the end of 2011.
- Even LHC people come to the Tevatron as a source of crucial comparison data and knowledge.

CPV

CP violation: why it is important

[A. Masiero, FNAL Users' meeting 2008]

A FUTURE FOR FLAVOR PHYSICS IN OUR SEARCH BEYOND THE SM?

- The traditional **competition** between direct and indirect (FCNC, CPV) searches to establish who is going **to see the new physics first** is no longer the priority, rather
- **COMPLEMENTARITY** between direct and indirect searches for New Physics is the key-word
- Twofold meaning of such complementarity:
 - i) **synergy in “reconstructing” the “fundamental theory”** staying behind the signatures of NP;
 - ii) **coverage of complementary areas of the NP parameter space** (ex.: multi-TeV SUSY physics)

Add to it the unsolved question of Baryon Asymmetry

Tantalizing Hints

- The D0 results on lepton asymmetries is only the last of a series of hints:
 - The 5- σ difference in Direct CPV in $B^0 \rightarrow K^+ \pi^-$ $B^+ \rightarrow K^+ \pi^0$ from Y(4S) experiments.
 - Slight excesses in $B^0 \rightarrow K^* \ell \ell$ FB asymmetry
 - Difference in $\sin(2\beta)$ between ccbar/penguin
 - Hints of nonzero mixing phase in the Bs
- All point to an anomalous source of CPV around the corner, and provide a strong motivation to investigate further.

Comments from A.Soni (EPS09)

Summary & Conclusions (I)

- While for now no compelling evidence against CKM-picture, several fairly sizeable effects ($\sim 2 - \sim 3.5 \sigma$) in B,Bs CP asymmetries are difficult to understand in SM3.
- Being careful, “conservative” & cautious in such instances means **hunting down seriously the underlying cause...** Effects may well have been misinterpreted (downplayed) rather widely in the US with detrimental implications.
- CDF/D0 finding of Bs \rightarrow psi phi “anomaly” is especially interesting since, 1) it follows from others, 2) unlike the other effects, this is theoretically very clean. Consequently, it is **extremely important that FERMILAB follows it up & clarifies it with a very high priority.**

The strengths of the Tevatron

- **Strengths:**
 - Large hadronic production: more fully reconstructed B hadrons than at $\Upsilon(4s)$
 - p-pbar symmetric initial state: low asymmetry systematics, needed for sub-% resolution
 - Hi-resolution central detectors
 - A refined trigger, with hardware online vertexing
 - The weight of accumulated experience
- **Some parts of the program are unique.**
 - Even those that are not, are important enough to justify the need for more than a single experiment
 - Their deliverance at the Tevatron is virtually certain
 - They come at no cost as part of the package

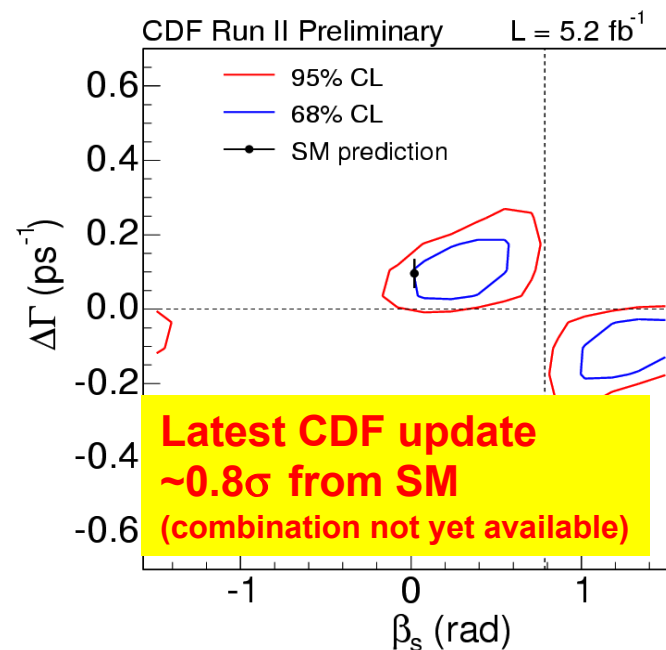
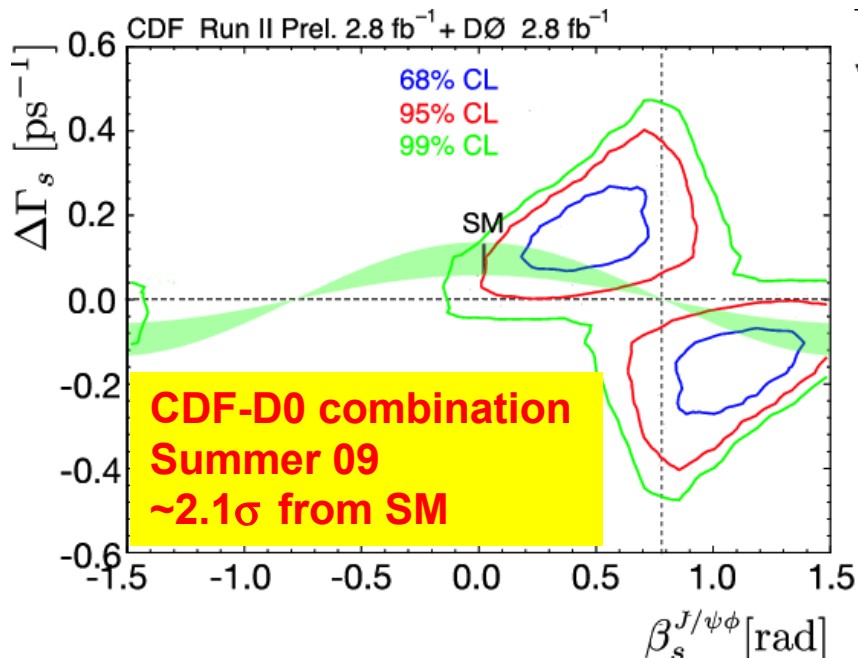
CPV in Bs mixing status

- The parameters of the Bs mixing are good probes into BSM
- Δm_s - precisely known, agrees with SM within theory uncertainty

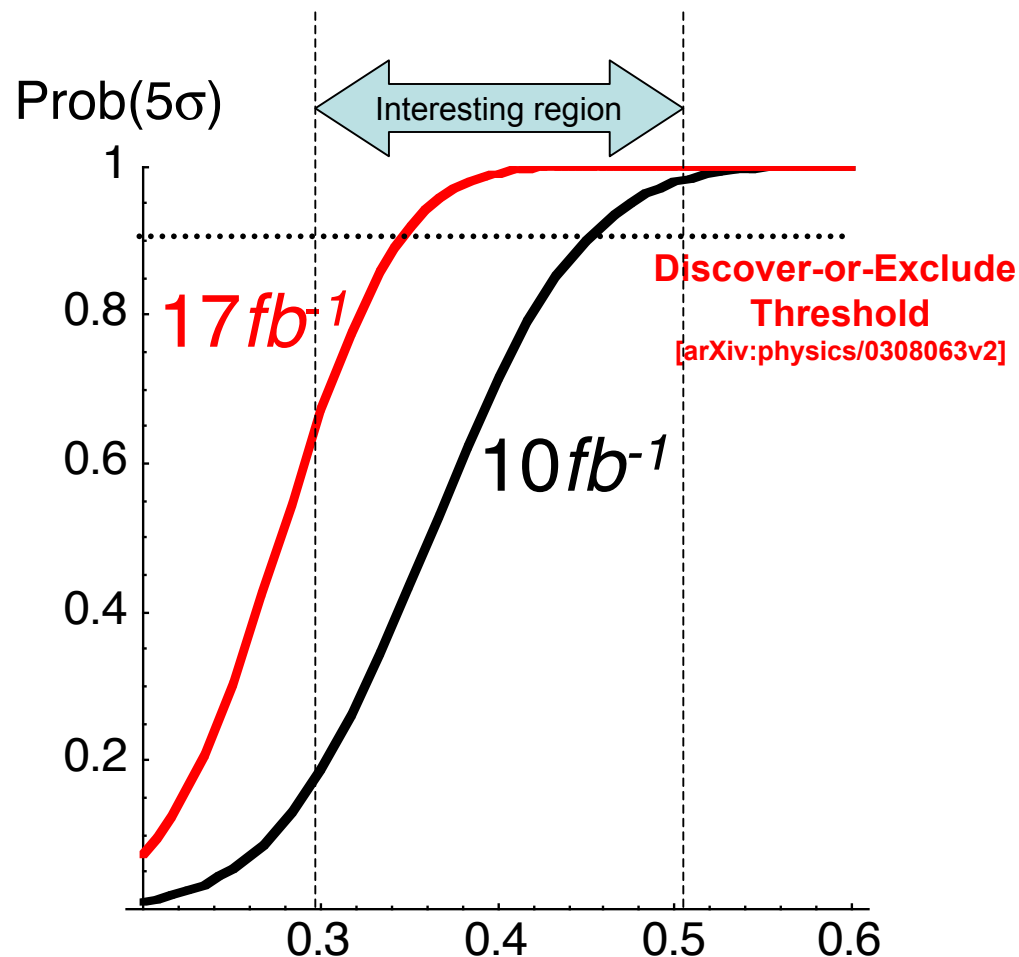
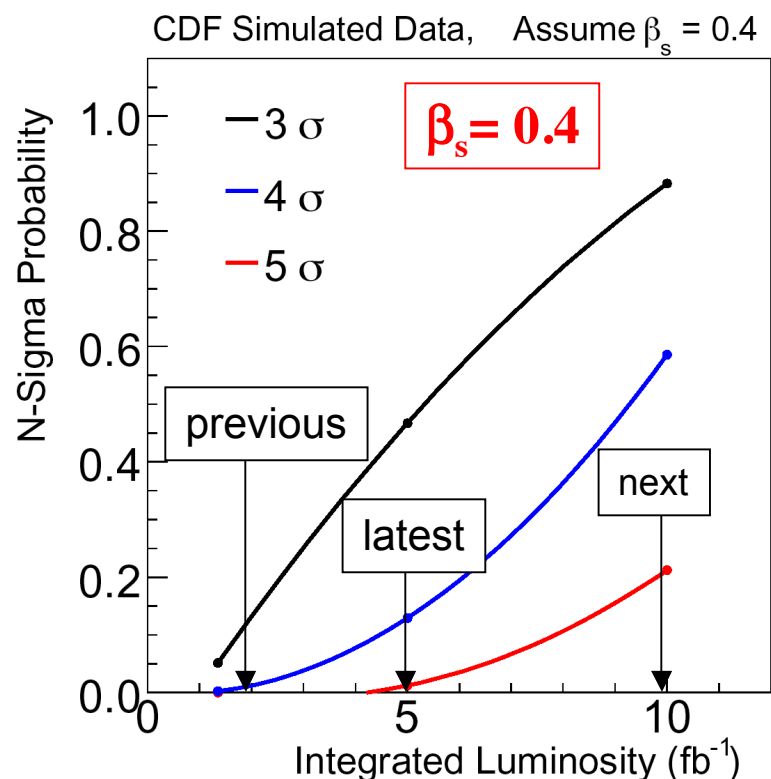
$$\Delta m_s = 17.77 \pm 0.10 \pm 0.07 \text{ ps}^{-1}$$

- The phase $\phi_s^{J/\psi\phi} = -2\beta_s^{J/\psi\phi}$ is the most interesting item. Small in SM, can receive large BSM contributions. PREDICTED to be large in some models
- Hints of deviations have raised strong excitement
- Must be large to produce large A_{SL} :

$$A_{SL} = (\Gamma_{12} / \Delta m_s) \cdot \sin(2\beta_s)$$



β_s Outlook for run III



- **Significant increase in discovery probability**
 \Rightarrow Enough data for a *yes/no* result (discovery or exclusion) over most of the interesting range.

- Assumes constant data taking efficiency and no analysis improvements
- No external constraint or additional information (e.g. ASL)

$\Delta\Gamma_s$ outlook

- Width difference $\Delta\Gamma_s$ is related to phase:

$$\Delta\Gamma_s = \Gamma_L - \Gamma_H \approx 2|\Gamma_{12}| \cos(\phi_s)$$
- If large phase, must be decreased from its SM value:

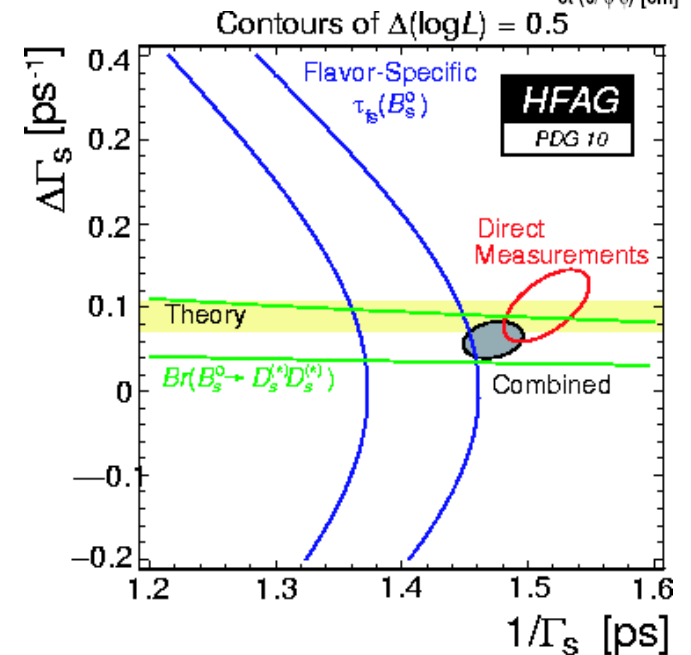
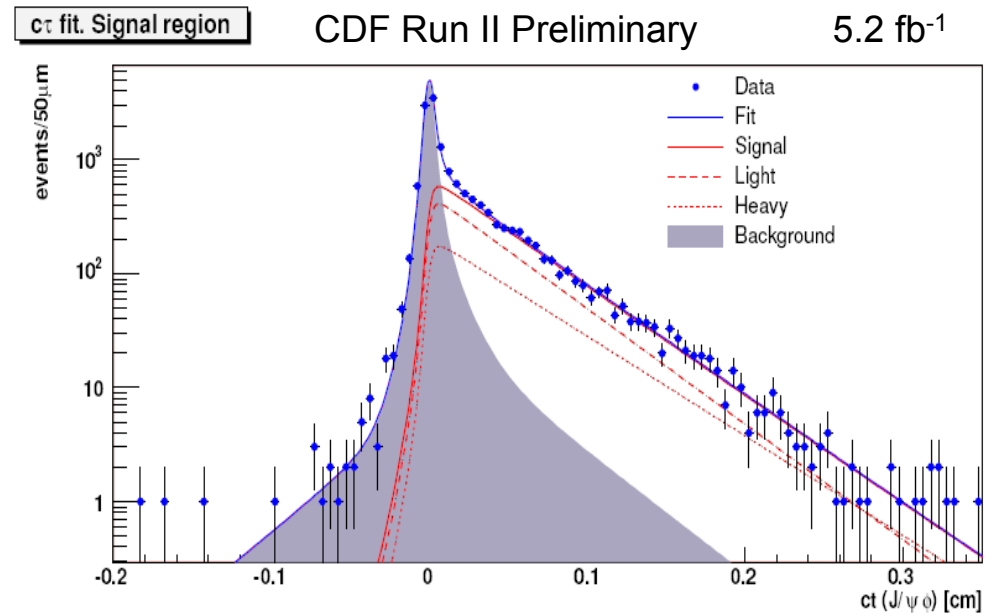
$$\Delta\Gamma_s = 0.088 \pm 0.017 \text{ ps}^{-1}$$
[JHEP0706:072,2007]
- It can reveal new physics on its own.

Latest Measurements:

D0 (2.8fb-1) $\Delta\Gamma_s = 0.14 \pm 0.07 \text{ ps}^{-1}$

CDF(5.2fb-1) $\Delta\Gamma_s = 0.075 \pm 0.035 \text{ ps}^{-1}$

Run 3 statistics: $\sigma(\Delta\Gamma_s) = 0.016 \text{ ps}^{-1}$
 5- σ between SM and zero.



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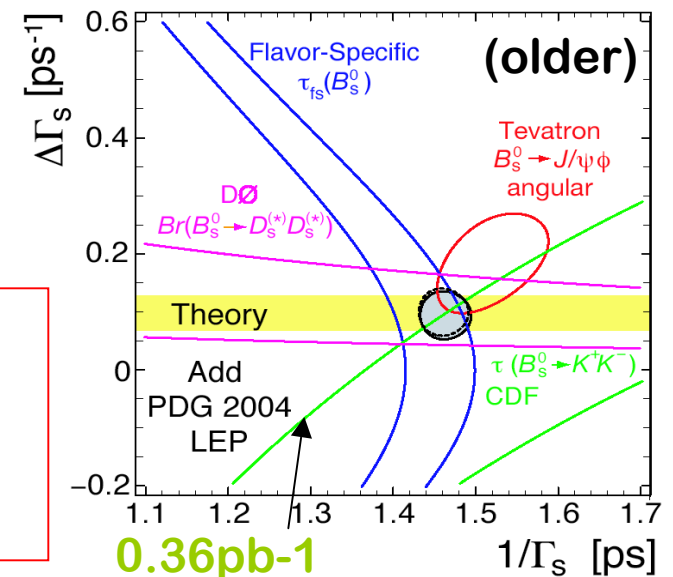
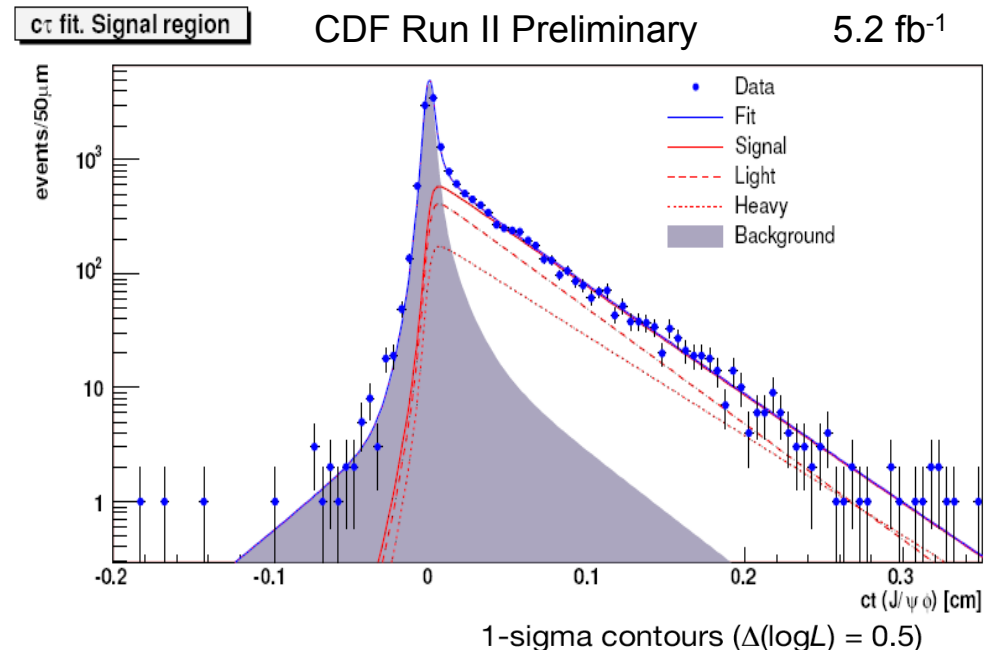
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With run3 the hadronic $B_s K K$ channel become important independent contribution (unique to CDF):

$\sigma(\Delta\Gamma_s / \Gamma_s) = 0.035$ (4σ level)



2nd part of comments from Soni

Summary & Conclusions (II)

- If the effects stand further scrutiny, **SM4 with m_t' , m_b'** (400-600 GeV) provides a v. simple explanation of the anomalies.
- SM4 opens up important new avenues for baryogenesis, DMC, unification, and most likely also crucial for EWSB...thereby it may well lead to a possible resolution to the hierarchy problem.
- Underlying nature of the “4th gen.” has to be significantly diff

On more general grounds BCP-anomalies means relative low scale for NEW PHYSICS with lots of accessible manifestations at LHC but also, for sure, means that SBF & (S)LHCb will have a very important role to play

World's best DCPV measurements

A whole array of DCPV measurements are the best existing. Improving them will cover **new and promising territory** from multiple directions.

- $A_{CP}(J/\psi K^+)$

4th generation predict $O(1\%)$ [PRL 95 (2005) 141601]

Best B-factory result: Babar $\sigma = 1.4\%$

D0 published 0.6% statistical

CDF expect 0.4% statistical in 5fb^{-1}

Run 3 statistics allows observation at 5 sigma

- $A_{CP}(B_s \rightarrow K\pi)$

A crucial test of the SM nature of CPV in B^0 and B^+

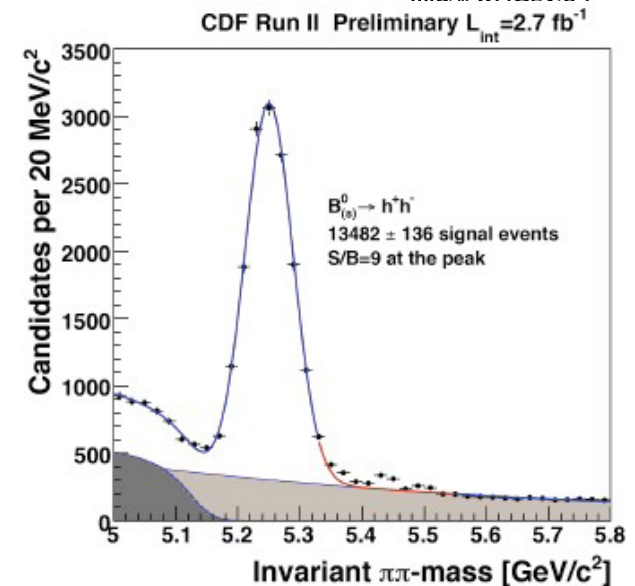
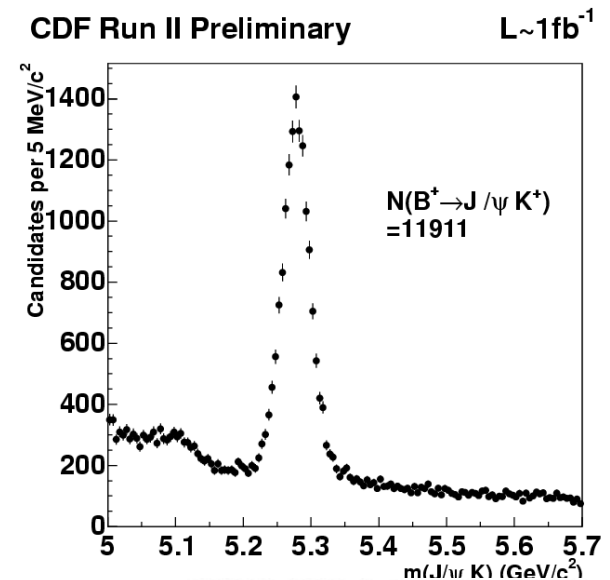
Unique to CDF. Will measure with $\sigma = 0.05$

- $A_{CP}(K\pi)$

CDF has World's largest sample ($3\text{k}/\text{fb}^{-1}$)

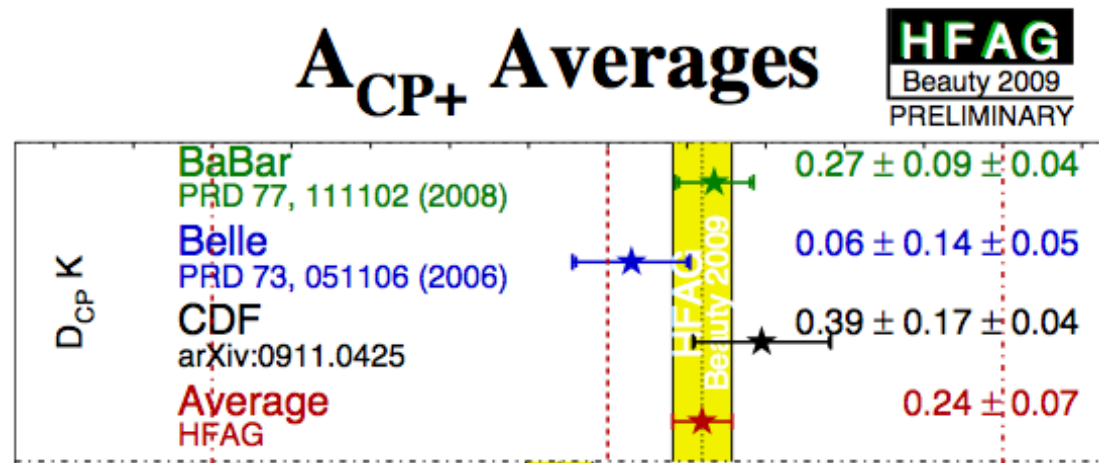
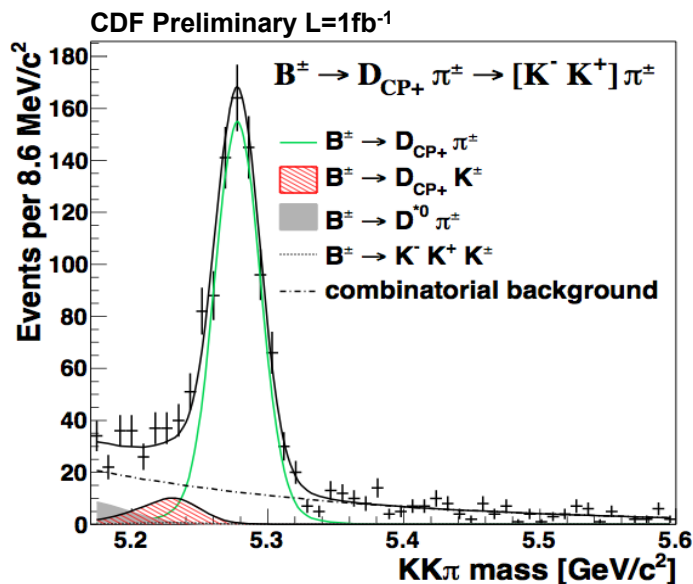
will measure $A_{CP}(K^+\pi^-)$ to $< 1\%$

World's best resolution on the first anomaly.



Further CPV: angle γ

- A further way to test consistency of CKM scheme
- Measurements in hadronic channels hard to do without an hardware vertex trigger

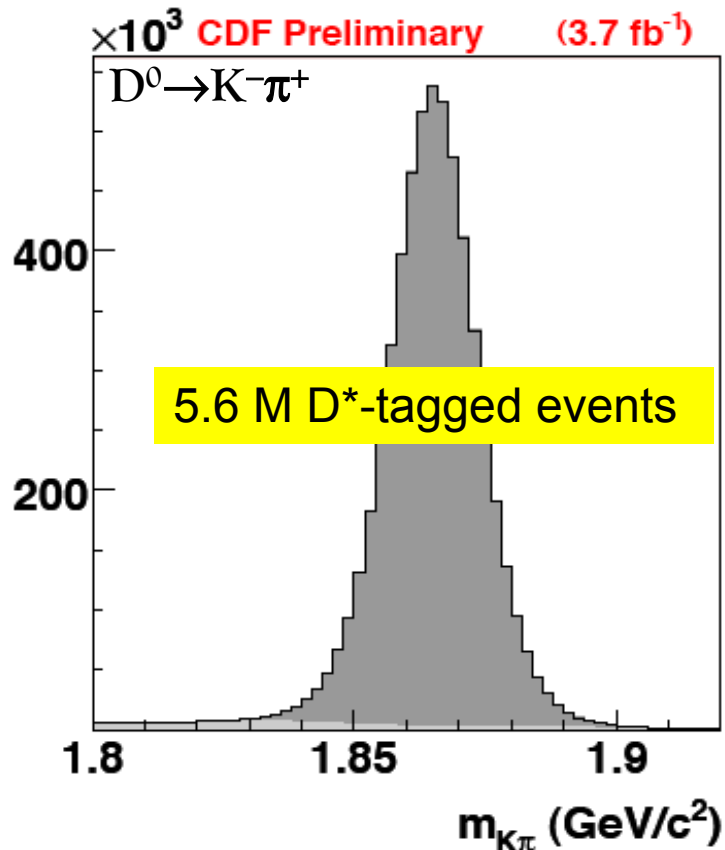


Current CDF published results from 1fb^{-1} only

1fb^{-1} CDF $\equiv \sim 350\text{fb}^{-1}$ @B-factory
 10fb^{-1} CDF $\equiv \sim 3.5\text{ab}^{-1}$ @B-factory

RUN 3 adds a good chunk of data

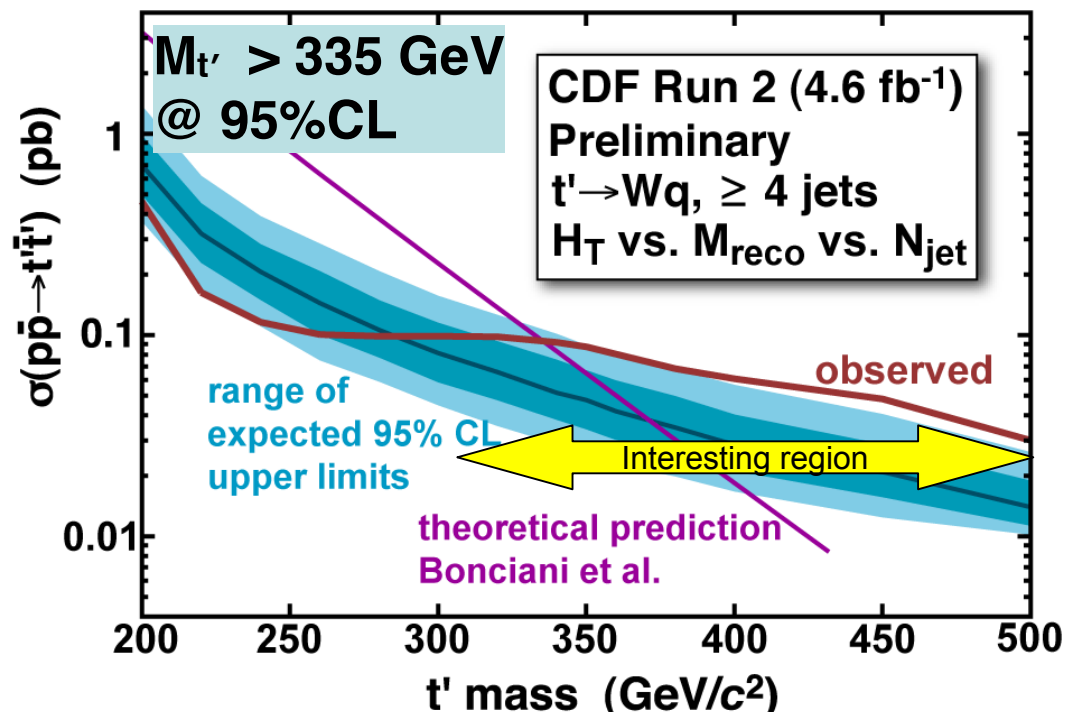
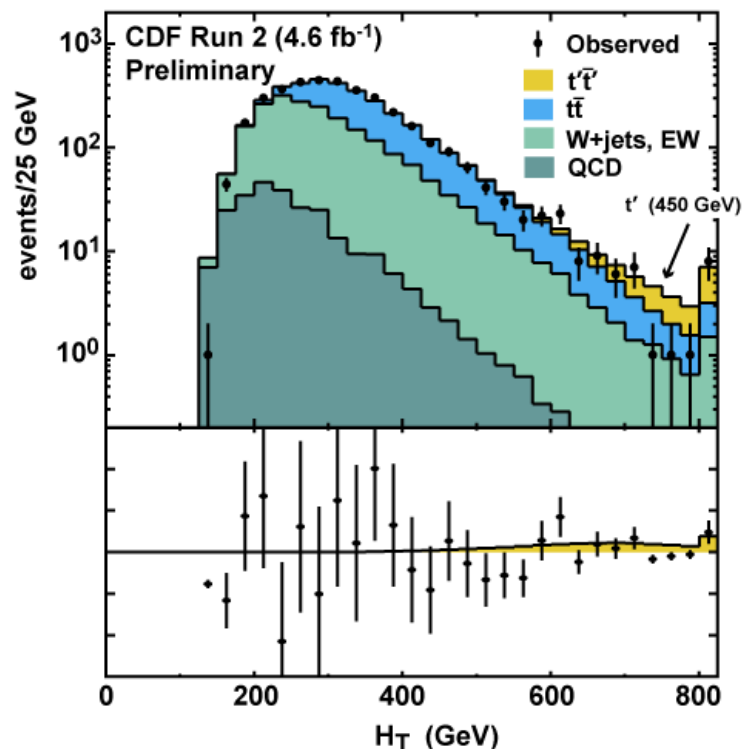
The cleanest, highest-intensity charm factory on earth



- CDF accumulates at rate **10x**Belle (at peak) using a vertex trigger. Enough motivation for a dedicated experiment.
- Recently added dedicated trigger selection.
- CPV in CS modes of D^0 unambiguous sign of NP (expect $O(1\%)$). [Phys.Rev.D75:036008,2007]
In particular from 4th-gen [hep-ph/0611154]
- Current PDG (Babar+Belle+CDF)
 $\sigma(A_{CP}(D^0 \rightarrow \pi\pi)) = 4.0 \cdot 10^{-3}$
- Tevatron run III hits the needed **$1.0 \cdot 10^{-3}$**
- Very likely the **ONLY** chance to observe CPV in the charm sector.
- **NO OTHER EXPERIMENT CAN ACHIEVE THIS SENSITIVITY** (possibly superB?)
- Bonus: high-precision determination of D^0 mixing parameters.

Direct test for the existence of a 4th sequential generation of quarks

- A very good explanation for the pattern of hints emerging is the presence of a sequential 4th generation of quarks of 300-500 GeV
- This would provide a solid explanation for the BAU, and EWSB.
- It can easily make the the Higgs boson invisible or push it to high masses (>300 GeV), so very important to test if it is there.
- Past CDF measurements show hints at 2.5 sigma level.

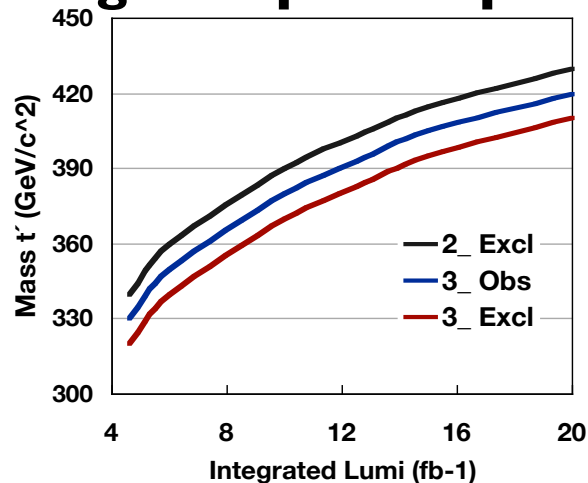


Direct test for the existence of a 4th sequential generation of quarks

- We don't need to speculate on the existence of a 4th generation
- **If it exists, it cannot be far from our current limits, and we will find out.**
- The current slight excess would turn into solid observation.
- If we don't find it, we will exclude an important candidate explanation

CDF-only projections, expect similar from D0
Expect joint sensitivity beyond 450GeV

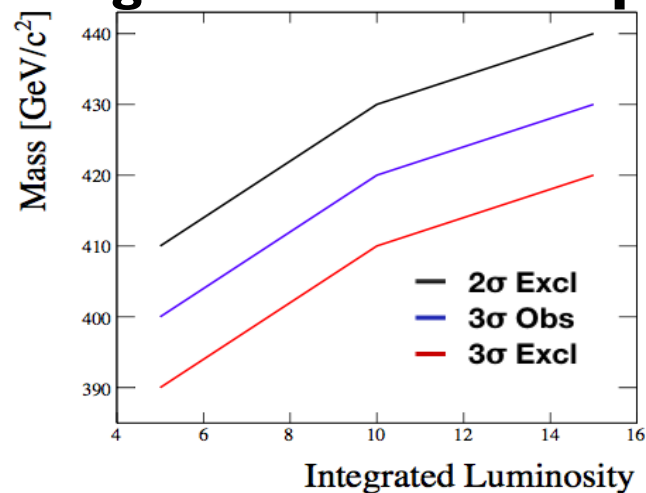
4th gen top-like quark



Current Limits:

$M_{t'} > 335 \text{ GeV @ 95\%CL}$

4th gen bottom-like quark



Current Limits:

$M_{b'} > 338 \text{ GeV @ 95\%CL}$

Other anomalies may surprise us: e.g. Top Properties

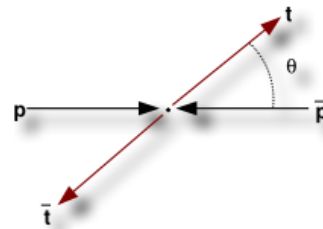
- NLO QCD predicts non-zero forward-backward asymmetry in top production $\sim 5\%$
- Measurement of A_{fb} can only be done in p-pbar
- Currently see an excess - Several new physics models predict large A_{fb} (Axigluons)



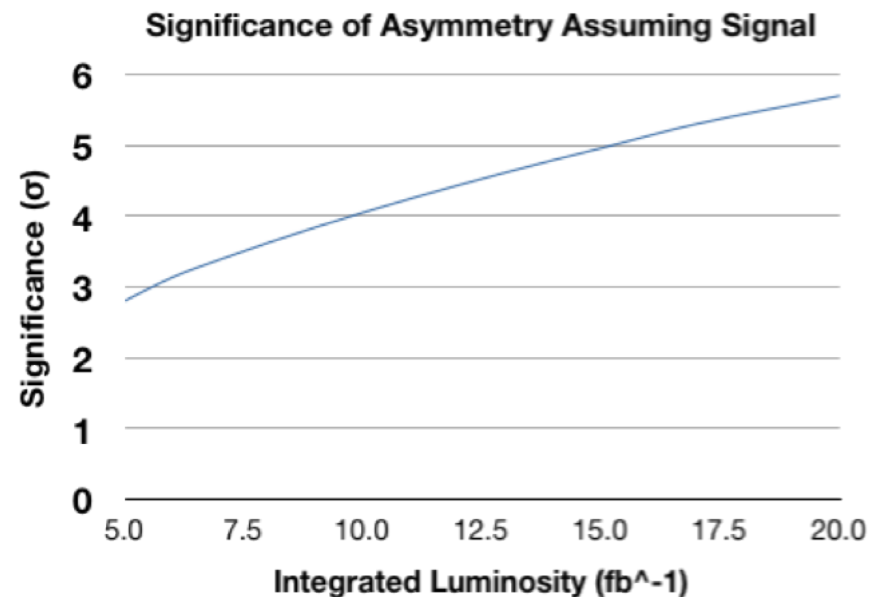
$$A_{fb} = 19 \pm 7 \%$$



$$A_{fb} = 12 \pm 8 \%$$



$$A_{fb} = \frac{F - B}{F + B}$$



SOME IMPORTANT QUESTIONS WE CAN ANSWER WITH RUN 3

- ARE THE ANOMALOUS CPV HINTS REAL ?**
 - IS THERE CPV IN THE CHARM SECTOR ?**
 - IS THIS DUE TO A 4TH GENERATION OR
SOME OTHER BSM SOURCE OF CPV?**
-

**The next talk will discuss THE UNIQUE
CONTRIBUTION OF THE TEVATRON TO
THE UNDERSTANDING OF EWSB.**